PSEUDOS - Chlorit.

a. Garnet

PUMPELLY

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# ON PSEUDOMORPHS OF CHLORITE AFTER GARNET

AT THE

SPURR MOUNTAIN IRON MINE, LAKE SUPERIOR.

BY RAPHAEL PUMPELLY.

With a Plate.

Fig. I.
$\frac{22}{1}$

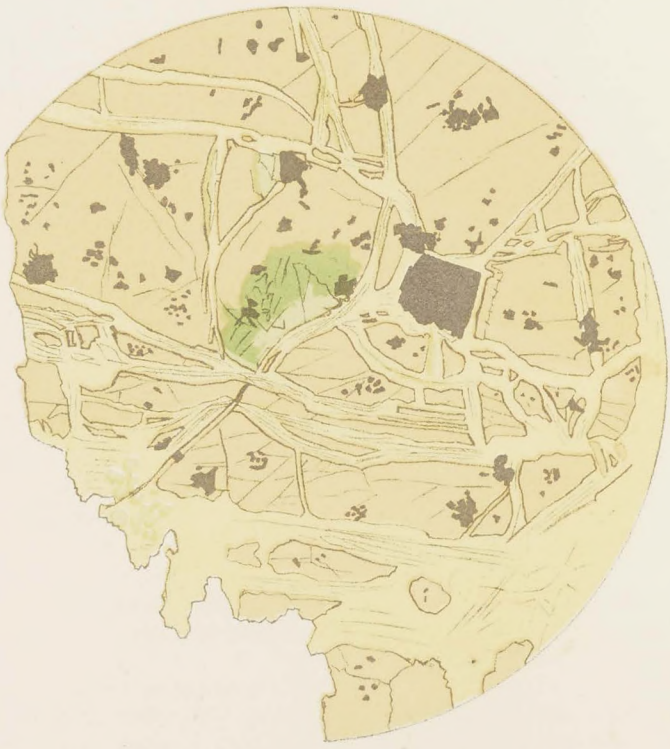
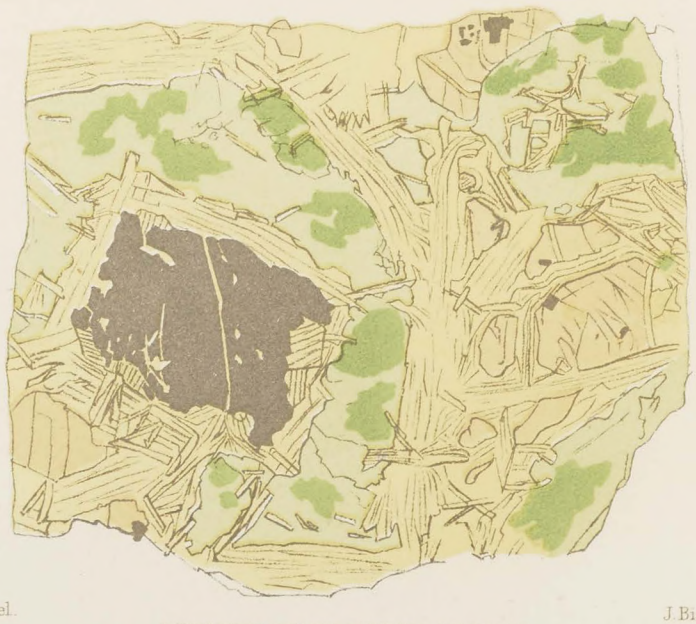


Fig. II.
$\frac{33}{1}$



Author, del. J. Bien, lith.

PSEUDOMORPH AFTER GARNET.

Remnants of Garnet | Chlorite | Magnetite & Discoidal Plates | Chlorite

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PSEUDOMORPHS of garnet occur in abundance in a bed of chloritic schist, just overlying the great magnetite bed of the Spurr-Michigamme iron range.*

This schist is of Archæan age and belongs in the upper beds of the Huronian iron series. It is a very fine-grained, dark green chlorite, which gives a light green streak and powder, dissolves in acids leaving a deposit of silica, and fuses B.B. on the edge to a black magnetic enamel (fus. = 4.) It is impregnated with octahedrons of magnetite, which rarely reach a diameter of one-eighth inch. Throughout the rock are scattered the pseudomorphs in very sharply defined rhombic-dodecahedrons of all sizes below 1½ inches in diameter. Often perfect crystals can be easily detached from the matrix.

On breaking the crystals and polishing the surface of fracture, they are found to be changed more or less to chlorite, in some instances specimens an inch in size containing not more than five per cent of garnet, while in others 30–50 per cent of unaltered mineral is present.

The octahedral crystals of magnetite are scattered through the pseudomorphs. They are visible to the naked eye, half imbedded on the surface planes, and in the interior of the crystals, both in the chlorite and in the unaltered garnet.

I have made several thin sections passing through the middle of crystals, about one inch in diameter, and have studied them under the microscope, making such examination of the optical characteristics as the nature of the minerals and the limitations of the method would permit.

* I am indebted to Dr. Cobb, the agent of the mine, and to Col. F. Norvell, general manager, for several hundred fine specimens of these pseudomorphs.

Under a one-tenth inch objective (500 diameters) the garnet appears not to be strictly homogeneous in texture; it has a curdled structure, particles of a transparent bluish-white filling the irregular meshes of a less clear, white net-work. Both of these portions of the garnet are isotrope, remaining dark through a full revolution between crossed nicols. Throughout both of these members are scattered exceedingly minute particles of a transparent red substance (hematite?) and larger opaque grains and discoidal plates.

A glance at a section under a low power shows that the change has taken place by an attack on the garnet along the countless fissures that traverse it in every direction (fig. 1), progressing most rapidly in the larger cracks, and ramifying through the more minute ones.

Two substances, one greenish-yellow, the other clear green, seem at first sight to be among the products now forming the pseudomorphs, though, as we shall see, they both probably belong to the same mineral.

I. The slightly greenish-yellow mineral (fig. 1) surrounds the remaining garnet fragments in bands which are in places clear and transparent, and in others are marked with longitudinal wavy lines, which probably indicate the cleavage of the mineral. From these broader bands, narrow ones branch off to form an intricate net-work in the garnet fragments. The same mineral occurs in isolated and grouped, long and slender crystals, which often branch out from or intersect the bands; while in other places the bands are often made up of these crystals, arranged more or less parallel to each other.

These bands are generally $\frac{1}{1000}$ to $\frac{1}{100}$ of an inch wide, and under a low power (figs. 1 and 2) their edges are sharply defined. Where a garnet fragment has been entirely destroyed, its place is occupied by an interwoven mass of them, often associated with irregular patches of the green substance described below. Under a high power, both the transparent red particles and the opaque grains and plates that were noticed in the garnet, are observed in this alteration-product.

These bands, when observed with only one nicol—the polarizer—show a high degree of absorption for intensity, and an appreciable amount for color, changing from very dark (with bluish-green tint), when the longer direction is parallel to the undulation plane of the nicol, to very light (with greenish-yellow tint) when perpendicular to that plane. Assuming that the parallel sides of the bands are crystallographic outlines and that they lie either in the basal plane, or else parallel to the principal crystallographic axis, I have attempted to determine optically the system to which these crystals belong. The method followed is that recom-

mended by Tschermak in distinguishing pyroxene, hypersthene and biotite. Having carefully adjusted the microscope,* so that the cross hairs in the ocular coincided exactly with the undulation planes of the crossed nicols, I first selected an individual, generally a long one with straight sides, and brought it by means of one of the cross-hairs into parallelism with the undulation plane of one of the nicols, and then revolved the stage till the nearest point of maximum darkness was reached, when the principal sections of the crystal coincided each with a principal section of a nicol's prism. The number of degrees of this revolution indicate the inclination of the principal sections of the crystal to the crystallographic feature chosen for reference.

Of course, if the mineral were either uniaxial or orthorhombic, the maximum of darkness would occur when two of the axes of the crystal were parallel to the undulation planes of the nicols, and there would be no revolution required. But this could occur in a monoclinic crystal only when one of the principal sections happened to coincide with the plane of symmetry; in every other position the axes of the crystal would make with its principal sections an angle which would vary between 0° and the number of degrees representing the inclination of the bisectrices to the vertical and inclined lateral axes; the full amount of this inclination could only be observed when the principal sections of the crystal were perpendicular to the plane of symmetry, but any inclination suffices to determine that the crystal belongs to a clinobasic system. Observations on a great number of the bands and isolated crystals failed to show any inclination; the mineral, therefore, does not belong to a clinobasic system.

II. The clear green portions occur isolated in the garnet fragments, and in places in the fissures with the mineral last described, and more or less diffused through the larger bands, but more generally in irregularly-shaped spots, and with outlines which are not necessarily determined by those of the garnet fragments. These larger areas exhibit lamellar aggregate polarization both between crossed nicols and with the polarizer alone. Between crossed nicols portions remain wholly dark during a revolution, some show only a faint change, and others are not distinguishable from the substance forming the bands, except that the cleavage lines are not so distinct. So also with one nicol, the portions that remain dark between crossed nicols show no absorption, while other portions change from clear green to almost colorl ss faint green-yellow, and still others show about the same changes as the bands.

* One of Beck's first class binoculars, in which the polarizer is attached to a sub-stage, and the main stage is graduated.

Again, we find in places, on the same individual, all these conditions, shading gradually one into the other in a manner that seems to indicate a bent crystal. I am inclined to look upon the bands and the clear green as identical, and as belonging to a hexagonal chlorite. The green portions would then be those which were cut more or less parallel to the basal plane, and the dichroitic bands those cut perpendicular to this.

While the plane of contact between the chlorite bands and garnet appears sharp under a low power, higher objectives (one-tenth or one-sixteenth inch) show it to have a rough surface caused by the projection of countless chlorite points into the garnet substance, in a manner that leaves on the observer the impression that the attack is facilitated in some way by the curdled structure of the garnet.

The chloritic schist which encloses the pseudomorphs consists apparently of exactly the same chlorite, the only perceptible difference being that in the schist the individuals are very minute, averaging ·00015 inch thick by ·0005 long, with scattering aggregations of crystals ·0008 by ·004 inch.

The optical characteristics of these larger, and so far as determinable, of the smaller, are identical with those of the chlorite in the pseudomorph.

The only other substances observed in the schist are minute octahedrons of magnetite and the discoidal plates which occur indifferently throughout the schist, the garnet substance, and the pseudomorphous chlorite. These plates average about ·00025 inch thick by ·00075 in diameter, and in reflected light have metallic luster. They are not attracted by the magnet and show no change after continued boiling in sulphuric and in muriatic acids. I had at one time the impression that they were graphite, but on comparing them with microscopic plates of that mineral in the Port Henry limestone, the difference in luster and fracture appeared very great.

These minute plates appear to me to be older than either the garnet or the chlorite—to have been enclosed in the original rock (argillaceous limestone?), and to have resisted the changes which successively produced the garnets and destroyed these and substituted chlorite for them and the original rock.

If this view is correct, the paragenesis should be as follows:

I. Original Rock (*Marl?*)

II. Metamorphic Change with crystallization of
  (*a.*) Octahedrons of *magnetite* and the *discoidal crystals.*
  (*b.*) Garnets.

III. Pseudomorphic Change. *Chlorite* after the original rock and after garnet, but preserving the magnetite and discoidal crystals intact.